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Performance of Water Wheel Knock Down System (W2KDS) for Rice Milling Drive

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Abstract*— The number of water wheels operated by the community in West Sumatra, Indonesia, in 1970 was around 4082 units, and now it is estimated that there are around 420 units. The water wheel system is made permanent, made of wood, the construction is quite heavy so that it becomes a problem when installing it. Water Wheel Knock Down System (W2KDS) is a good alternative and solution because the construction is light, and its components can be broken down so that it is easier to install in remote villages. The formulation of the problem of this research is how the performance of W2KDS driving rice milling? The research objective was to analyze W2KDS performance, transmission efficiency, and rice milling productivity. The research methodology is an experiment with the stages of designing W2KDS systems and components, building W2KDS-rice milling, and analyzing the performance of W2KDS driving rice milling. The type of W2KDS that has been successfully built is a breast shot with an outer wheel diameter of 180 cm, an inner diameter of 120 cm, a blade width of 60 cm, 20 blades, and a belt-pulley power transmission system. The results of the W2KDS performance analysis of rice milling driving are, at a water flow rate of 88 L/s, head of 5 m, and a rotational speed of 60 rpm, the resulting torque is 551 Nm, power 3400 W, W2KDS efficiency 78.1%, transmission system efficiency 88.2% and rice milling productivity of 86.40 kg of rice/hour.

***Keywords*— Performance; water wheel; knockdown; rice milling; drive; pico hydro.**

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I. INTRODUCTION

Developed and developing countries are very dependent on the availability and sustainability of energy, while world energy consumption soon continues to grow [1]. The people's standard of living continues to increase, and the world population continues to grow, resulting in greater energy demand. Hence, alternative energy technologies that produce clean energy and environmentally friendly meet the world community's needs [2]. Non-renewable energy sources such as coal, oil, and natural gas have limitations and often cause environmental problems. In contrast, renewable energy sources have a vital position so that the future of renewable energy is of concern to researchers and practitioners [3]. The exploitation of renewable energy resources continues to endeavor in response to increased electricity demand and problems that arise due to the use of fossil fuels [4]. Renewable energy technology is one solution for providing energy for the community, so proper investigation and research are needed to determine the ideal renewable energy technology [5]. Renewable energy innovation and development have increased rapidly in recent years [6]. Many solutions have been tried to solve the energy needs of the community. However, the problem of energy availability and quality has not been maximized, so that it becomes a challenge mostly felt by the people in the village [7]. Expensive investment is expensive, and the supply of energy sources that are not continuous becomes the main challenge in building renewable energy generation [8].

The distributed renewable energy generation system is a reliable, economical, and efficient electrification option that connects various energy sources. In renewable energy systems, the performance of reliable generating units has a strategic role. Implementation of maintenance that is disciplined, timely, appropriate, and appropriate in its utilization has a massive impact on the quality of service and generators' cost-efficiency. [9]. Many renewable energy sources can be used to obtain electrical energy from natural sources in the world [10]. For example, Indonesia is an archipelago that has enormous potential for energy resources, including water energy [11]. Hydropower plants have been proven to play an essential role in fulfilling renewable energy for the community. One of the challenges is that water turbines are not sold freely in the market; to get them, people must order in advance so that the price of turbines becomes expensive [12]. Conventional turbines used for small-scale hydroelectric power plants (pico hydro and micro-hydro) include crossflow turbines, Francis turbines, Pelton turbines and propeller turbines [13]. The use of a crossflow turbine in a pico hydro generator system, for example, can produce 8.9 kW of power at a flow speed of 18.84 m/s, a flow rate of 0.21 m^3/sec, and a head of 6 m with an optimal efficiency reaching 89% (14).

Small-scale water energy development has great potential to be developed in producing green energy, especially if it considers developing turbine and water wheel technology [15], for example, about changes in channel geometry that can increase the output power and performance of water wheels [16]. In remote or developing countries, water wheels are installed in irrigation canals [17]. There are three water flowing categories in irrigation channels, namely without head or shallow subcritical flow, superfast flow, and deep flow [18]. Shallow subcritical flow velocity is relatively constant, producing water energy on a pico hydro scale (output power <10 kW). A water wheel is a sustainable and economical technology because its construction is more straightforward than a water turbine, the environmental impact is low, the return period of investment is faster, practical and there are no obstacles in its installation. Water wheels can also improve the local economy by promoting water energy tourism, and water wheels can be used for grinding agricultural products and producing electricity [19]. A water wheel is not a strategic solution for large-scale renewable energy generation, but the water wheel is a generating system suitable for decentralized power plants [20]. A water wheel is a system suitable for low-head applications. Channel geometry has an essential effect on the water wheel's performance, and the channel size is twice as big as the wheels, which results in better water wheel performance [21].

Water wheels are of three types, undershoot, breast shot and overshoot types, and pitchback types [22], as shown in Figure 1. The first type of horizontal shaft water wheel found is the undershot water wheel, running water near the bottom of the pinwheel, pushing the blade so that the water stream's kinetic energy can be exploited. Conversely, water's potential energy is the primary energy source for overshoot and breast-shot water wheels. The efficiency of water wheel overshoot and breast shot is better than undershot, but the undershoot waterwheel technology is the simplest and most popular and is suitable for the low head [23]. The overshoot and breast shot waterwheel match the head 2.5 m to 10 m with a flow between 0.1 m^3/s to 0.2 m^3/s, and the efficiency reaches 80% [24]. Water wheel power can be analyzed using computational fluid dynamics or experimentally. The effect of several parameters can be adopted, which allows the ability of waterwheels in the future to be optimized [25]. Several innovations have been made to improve waterwheels' performance, including water wheel-triboelectric nanogenerators (ww-TENG) technology. The present ww-TENG shows excellent potential for harvesting the kinetic energy from flowing rivers and targets for large load resistance applications such as electrostatic systems [26].

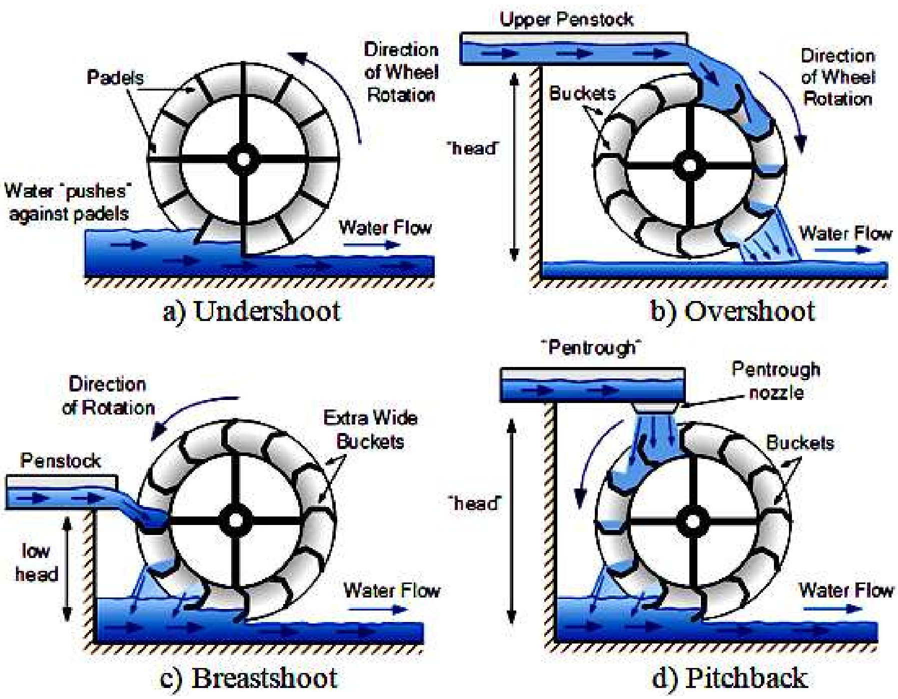


Fig. 1 Four types of water wheels

The number of water wheels operated by the community in West Sumatra, Indonesia, in 1970 totaled around 4082 units, the number has continued to decline, and it is now estimated that around 420 more units are functioning, such as rice pounders, flour crushers, and power plants. The water wheel system is made permanent, made from high-quality wood, and the construction is quite heavy. Furthermore, through several studies, researchers succeeded in building four breast shot permanent water wheel units made of steel plates that function as power plants. However, because of its large size and weight, it becomes a challenge when transporting, installing, and testing it as shown in Figure 2-4 [27].

Fig. 2 Permanent water wheel will be taken to the testing site

Fig. 3 Drop in the water wheel around the plant site

Fig. 4 Communities have difficulty pushing permanent water wheels to be installed

Due to the water wheel testing location in isolated villages, on the banks of rivers, and under challenging valleys to facilitate transportation and installation, the researchers succeeded in building the Water Wheel of Knock Down System (W2KDS). With the knockdown system, the water wheel system can be assembled into several small components to be more accessible when transporting and installing. The W2KDS component can be carried in a small pickup truck to the test location, and after arriving at the location, all components are assembled, installed, and tested. The W2KDS assembly process is quite fast, symmetrical construction, sturdy and compact so that the W2KDS can operate stably.

Furthermore, from this study's success, researchers were inspired to develop W2KDS activators of rice milling. W2KDS combination - rice milling benefits the community more because it does not need fuel oil so that production costs are cheap. This is a study of the development of renewable energy that is realistic considering the energy potential of the pico hydro scale is quite a lot in villages in West Sumatra, Indonesia. W2KDS-rice milling performance testing includes torque, power, W2KDS efficiency, transmission system efficiency and rice milling productivity.

II. Material and Method

A. Research Sites

The research location is in Manggis Village, Koto Parik Gadang Diateh District, South Solok Regency, West Sumatra, Indonesia, at the position of 101,06^0 EL coordinates and 1,509^0 SL, the layout around the test location is shown in Figure 5. Manggis Village is an isolated village that does not yet have an electricity network, and the distance from the highway is about 12 km through the village road. The survey results found a strategic location for the W2KDS-rice milling test location, where there is a potential head of about 5 m and the potential of river water flow is 160 L/s so that the technical aspects of Manggis Village deserve to be the testing location. The population of Manggis Village and its surroundings amounts to 20 families, most of whom work as farmers, and they are expected to be able to use the W2KDS to process their rice crops.

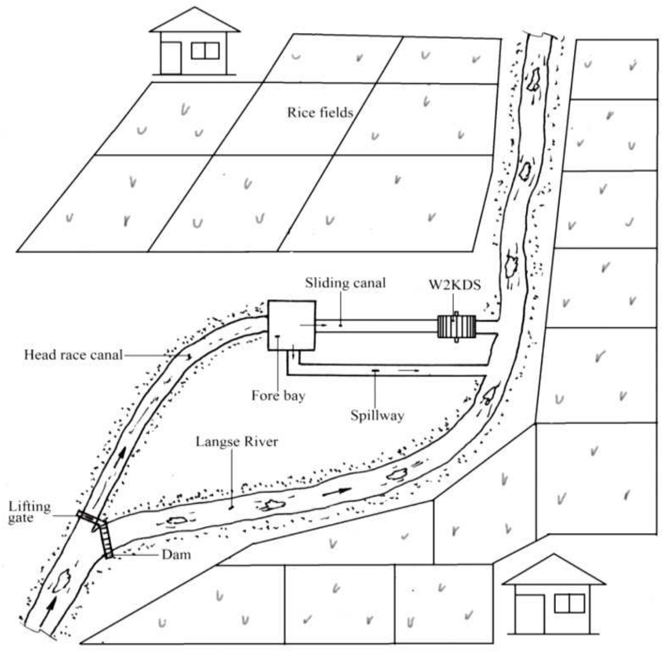


Fig. 5 Layout around the W2KDS testing location

B. Planning of W2KDS System

Planning includes determining the W2KDS system, civil building planning, and mechanical equipment planning. Civil buildings consist of dams, canal head races, fore bays, sliding canals, spillways, sewers, and powerhouses. Mechanical equipment consists of filters, sluice gates, wheels, shafts, bearings, and transmission systems. The main variables of planning the W2KDS system are maximum discharge (Q): 90 L/s and effective head (H): 5 m. The W2KDS system, as shown in Figure 6, is constructed of civil buildings from the pair of times the masses are smoothed. A 3.2 mm thick steel plate dominates the material for making mechanical equipment to make 20 pieces of blade, two rings, and one main ring. By considering the ease of manufacture and transportation, it is planned that the outer diameter of the wheel (D_o): 180 cm, the inner diameter (D_i): 120 cm, and width (L_r): 60 cm. The ratio of width to the wheel's outer diameter is L_r/D_o: 0.33, while the recommended L_r/D_o ratio is up to 3.5 [28] as shown in Figure 7. The connection between water wheel components using an M10 x 30 mm bolt-nut of 120 galvanized material of 80 pieces for blade connection with two main rings and 40 pieces for blade connection with the inner ring.

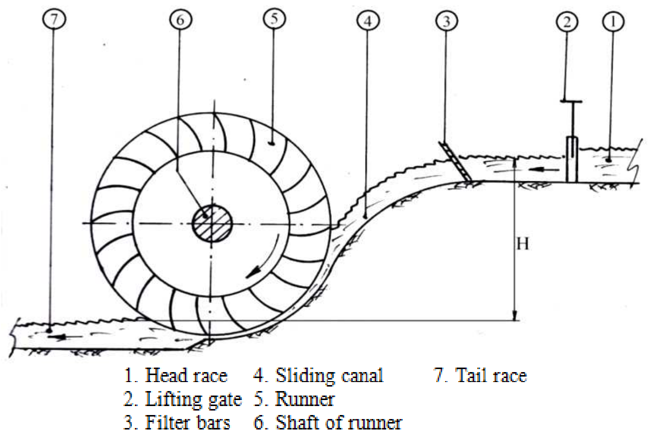


Fig. 6 W2KDS system

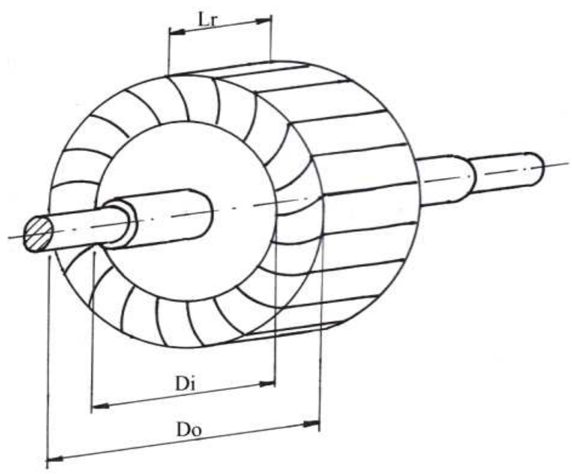


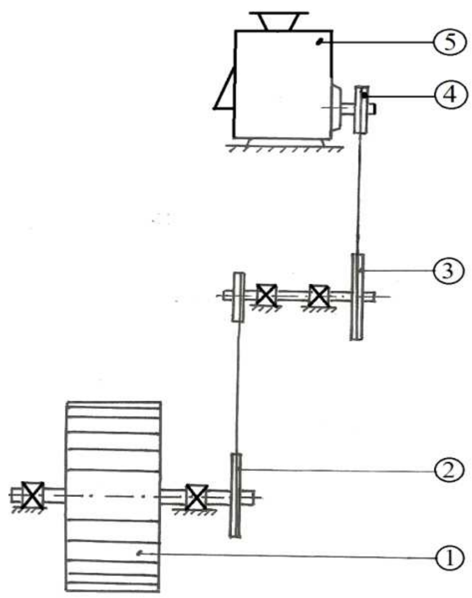
Fig. 7 The main dimensions of the wheel

C. Planning of the Transmission System

The power transmission system of the W2KDS to the rice milling uses a two-stage belt-pulley system, type B, four grooves. The W2KDS shaft pulley's rotation speed is 60 rpm, while the rice milling shaft's rotation speed is 900 rpm. By assuming losses of around 10%, the rice milling shaft's rotation speed is plotted at around 990 rpm, then the ratio of transmission system rotation speed is 16. Each level's speed ratio is planned 4, so for the first and second levels of the drive pulley diameter and each driven-each is 20 inches and 5 inches. The planned transmission system is shown in Table 1, and Figure 8 describes the specifications of the W2KDS-rice milling system components.

TABLE I
SPECIFICATIONS FOR W2KDS-RICE MILLING SYSTEM COMPONENTS

No	W2KDS system Components	Specifications
1	Cross-section of the water canal	
	a. Head race canal	80 cm × 60 cm
	b. Sliding canal	60 cm × 50 cm, α: 45°
	c. Tailrace	80 cm × 50 cm
2	Runner W2KDS	
	a. Blade	60 × 40 cm, thick: 3.2 mm (20 pieces)
	b. Main ring	D_o: 180 cm, D_i: 120 cm, thick: 3.2 mm D_n : 120 cm, b : 60 cm, thick : 3.2 mm
	c. Inner ring	d: 3.5 inch, l: 140 cm
	d. Shaft	R : 70 cm, steel profile U
	e. Wheel crossing	Roll Bearing, SKF d_b : 80 mm
	f. Bearing	D : 40 cm, thick : 12 mm
	g. Disk	
3	Transmission system	Two-stage belt pulley
	a. Drive pulley	D_d: 20 inches, type B, four grooves, 2 pieces
	b. Tail pulley	D_t: 5 inches, type B, four grooves, 2 pieces
4	Rice milling	
	a. Type	SB10D
	b. Rotational speed	900 – 950 rpm
	c. Dimension	860 × 740 × 1550 mm
	d. Weight	195 kg
	e. Power	3.0 kW



1. Unit of W2KDS
2. First stage drive pulley, 20 inches diameter
3. Second stage drive pulley, 20 inches diameter
4. Tail pulleys, 5 inches in diameter
5. Rice milling

Fig. 8 W2KDS-rice milling power transmission system scheme

D. Making, Assembling, and Installing

Making W2KDS components involves lathes, rolling machines, drilling machines, grinding machines, welding machines, and other workshop equipment. Figure 9–14 shows the assembly process, and Figure 14 shows the installation process and W2KDS-rice milling performance testing. In this test, the initial variables measured are water discharge, rotation speed, and generated torque.

Fig. 9 The process of rolling inner rings a water wheel

Fig.10 the process of making the water wheel main ring

Fig. 11 installation of 20 blades in the water wheel main ring

Fig. 12 W2KDS assembly around the plant is almost complete

Fig. 13 W2KDS installation on the stand

Fig. 14 Installation of W2KDS-rice milling combination

E. Technical Data Analysis

After the manufacturing, assembly, and installation stages of the W2KDS component, the next step is the W2KDS performance test on the four variations of lifting gate openings. At each lifting gate opening, the measurement of torque W2KDS (T), rotational speed W2KDS (N), theoretical power (P_t), effective power W2KDS (P_w), efficiency of W2KDS (η_w), transmission system efficiency (η_t) and productivity of rice milling (PRM). The torque that occurs can be determined by the braking mechanism at a certain rotation speed, as shown in the test scheme in Figure 15. The test equipment used consisted of bands and digital scales. In the braking process, the tension on the tight side (F_t) and the slack side of the band (F_s) will arise, the difference between F_t and F_s is obtained effective force (F_e). The torque that occurs can be searched by equation (1) [29].

$$T = Fe \times R \tag{1}$$

Where R is the pulley radius (R: 10 inches)

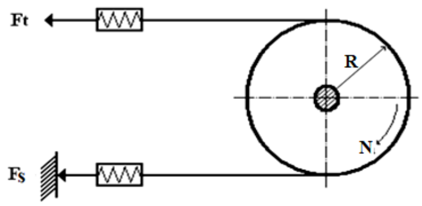


Fig. 15 W2KDS torque measurement scheme

The effective power of W2KDS (P_w) and theoretical power (P_t) can be known from equations (2) and (3) [30].

$$Pw = 6.28 \times N \times T / 60 \tag{2}$$

$$Pt = \rho water \times g \times Q \times H \tag{3}$$

ρ_{water} is the density of water (1000 kg/m^3). The efficiency of the W2KDS (η_w) can be seen from equation (4) [30].

$$\eta w = (Pw / Pt) \times 100\ \% \qquad (4)$$

III. Results and Discussion

The performance and characteristics of W2KDS tests were carried out in two influence tests, namely the effect of rotation variation on power, the effect of rotation variation on efficiency at the constant head, and the influence of discharge variation on power and efficiency at constant rotation. In this test, the head is constant (H: 5 m), which is the height difference between the water's surface in the soaking tub and the bottom of the water wheel minus losses along the sliding canal. The test was carried out in four variations of lifting gate openings: full opening (100%), 75% openings, 50% openings, and 25% openings. The variation of water flow into the windmill is carried out by changing the lifting gate openings located around the sedating basin. Each lifting gate opening was tested with eight variations of the rotation and rotation of the waterwheel known from the shaft rotation measurement using a tachometer.

A. Effect of Rotation Variations on the W2KDS Power at a Constant Head

The purpose of testing is to find out the optimum W2KDS rotation, which can produce maximum power, for that W2KDS rotation is varied in eight variations of rotation with random intervals. After the torque data (T) for eight variations of rotation are obtained, then the power of W2KDS can be immediately known as the results shown in column 5 in Table 2. The curve shows the W2KDS power trend for the eight variations of rotation in Figure 16.

TABLE II
W2KDS Test Data on the Position of Lifting Gate is Open 100%, Constant Head 5 m

No	Discharge Q (L/s)	Rotational speed, N (rpm)	Torque T (Nm)	W2KDS Power Pw (W)	Theoretic Power P_t (W)	W2KDS Efficiency η_w (%)
1	0.0	0	0.0	0	0	0.0
2	89.10	8	955.4	800	4371	18.3
3	91.13	16	955.4	1600	4470	35.8
4	81.90	32	767.6	2570	4020	64.0
5	88.84	60	541.4	3400	4360	78.1
6	80.24	83	317.1	2755	3935	70.0
7	82.16	100	193.0	2020	4030	50.1
8	81.53	110	68.2	785	2773	28.3
9	80.60	120	0.0	0	0	0.0

Figure 16 illustrates the parabolic curve of the effect of rotation on W2KDS power, which a quadratic equation can solve with the determination coefficient (R^2) close to 1. The parabolic curve starts from the center of the coordinates (0.0) so that each rotation that occurs will affect Direct variations in W2KDS power. This shows that no rotation value does not produce power. All four curves have the same shape, only the size is different, and between one curve and the other, the curves close together. This indicates that variations do not influence the trend of the effect of rotation on power in discharge alone. At the beginning of half the rotation interval, there is an increase in power, but after passing half the rotation interval, there is a decrease in power until it reaches the lowest power; the optimum rotation occurs in the middle of the rotation interval. The increase and decrease in power and rotation depend on the loading force applied.

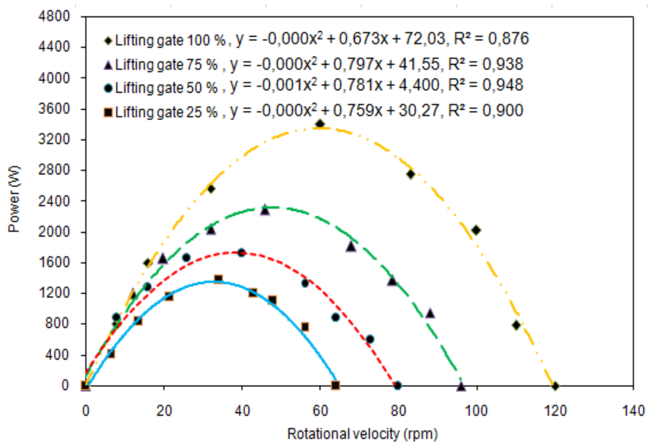


Fig. 16 Curve effect of rotational variations on W2KDS power

In Figure 16, the lifting gate's position is open 100%, producing more power than the maximum power in the percentage of other discharges. In the lifting gate open 100% produces a maximum power of 3400 W at an optimum rotation of 60 rpm. Maximum power in the lifting gate position is 75% open 2300 W and rotation 46 rpm. The maximum power at the position of lifting gate open 50% is 1720 W, and the rotation of 40 rpm and the maximum power at the position of lifting gate open 25% is 1380 W and the rotation of 35 rpm. Meanwhile, W2KDS does not produce power at 120 rpm, 96 rpm, 80 rpm and 65 rpm for the gate opening position to open 100%, 75%, 50%, and 25%.

B. Effect of Rotation Variations on the W2KDS Efficiency at a Constant Head

The purpose of the test is to analyze the effect of rotation variations on the efficiency of W2KDS and to analyze the optimum rotation, which produces maximum efficiency. The W2KDS efficiency value is the ratio of real power to potential power, as described in Table 2, column 7. The trend curve influences the rotation variation on the efficiency of W2KDS shown in the curve in Figure 17.

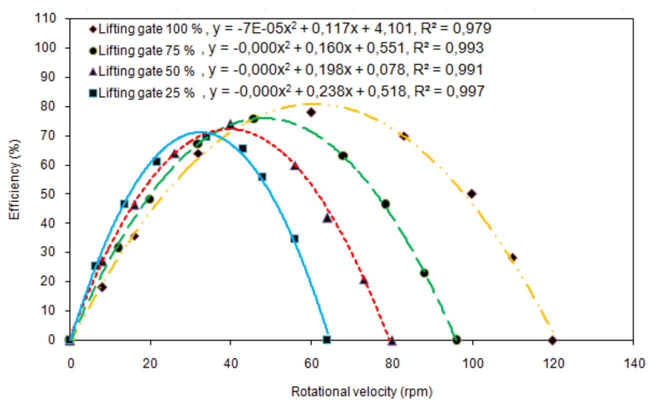


Fig. 17 Curve effect of rotational variations on W2KDS efficiency

Figure 17 explains the four efficiency curves have the same pattern, i.e. at the initial rotation, the efficiency of

W2KDS tends to increase, but after passing half the rotation interval, the efficiency of W2KDS continues to decrease until it reaches the lowest efficiency. Curve trends that occur produce a parabolic curve with a coefficient of determination (R^2) that is convincing, approaching the value of 1. This value shows that the diversity of efficiency values corresponds to the variation in W2KDS rotation values. No rotation period does not produce efficiency; this is following the curve of the influence of rotation on rising power. The smaller the percentage of lifting gate openings results in increasingly narrow turning intervals, but the trend of efficiency is climbing. The smaller the percentage of lifting gate openings, the W2KDS is increasingly sensitive to increased efficiency. High rotation does not show as the optimum rotation because the data proves that the highest efficiency is obtained in the position of half the rotation interval, and maximum efficiency of W2KDS of 78% is obtained at the optimum rotation of 60 rpm at the 100% open gate lifting position. The next maximum efficiency occurs in the position of lifting gate open 75%, 50%, and 25%, namely 75%, 74%, and 69.6% at 46 rpm, 40 rpm, and 34 rpm W2KDS rotation. This finding recommends that the W2KDS generator be built by the community to work optimally. The W2KDS must be operated at a cycle of between 60 rpm to 70 rpm in a fully open (100%) lifting gate position.

C. Effect of Discharge Variations on Power and W2KDS Efficiency

The test aims to determine the variation of power and efficiency of W2KDS due to the influence of constant rotational speed variations. Tests carried out on constant head (H): 5 m, constant rotational speed (N): 60 rpm and four variations of discharge with maximum discharge (Q_{max}): 90 L/s. The recapitulation of the analysis data is explained in Table 3.

TABLE III
DATA ON POWER ANALYSIS AND EFFICIENCY OF W2KDS

H (m)	Q (L/s)	Q/Q_{max}	N (rpm)	T (Nm)	P_w (W)	P_t (W)	η_w (%)
5	22.5	0.25	60	50	310	1100	28.0
5	45.0	0.50	60	210	1310	2210	59.2
5	67.5	0.75	60	390	2440	3310	73.6
5	90.0	1.00	60	551	3460	4415	78.4

Furthermore, the discharge, real power, and efficiency data are plotted into curves, and the results are shown in the curve in Figure 18. The trend of the effect of discharge variations on real power forms a linear curve which means that the water discharge has a consistent effect on real power W2KDS. From the linear curve, it is known that the maximum power of 3460 W occurs at the optimum discharge of 90 L/s with a maximum efficiency of 78.4%, the water wheel rotation is 60 rpm, and the head is 5 m. While the trend of the influence of debit variations on the efficiency of W2KDS forms a polynomial line, it means that the water discharge is not the only factor that influences the value of efficiency. However, there are other influential variables such as the quality of construction of water wheels, especially blade components. The polynomial curve produces a coefficient of determination (R^2) which is convincing, close to the value of 1, which means that the diversity of discharge values is proportional to the diversity of efficiency values. At the discharge interval of 14 L/s to 90 L/s, the water wheel efficiency trend continues to rise stably, at the discharge position of fewer than 14 L/s the water wheel has not been able to produce power, so its efficiency is the lowest. Discharge of water below 14 L/s is called a moderate discharge; water flow above 14 L/s to 90 L/s is referred to as effective discharge.

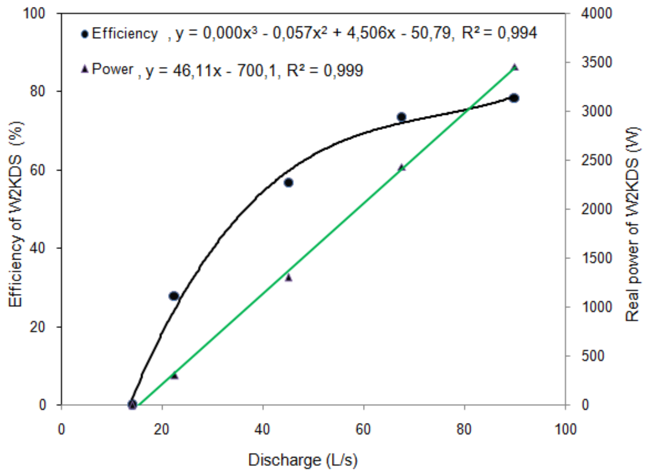


Fig. 18 Variation in the efficiency and real power of W2KDS versus discharge

D. Variation in Efficiency of W2KDS (η_w) due to the Influence of the Constant Discharge Ratio

Look at Table 3, and the discussion continued to find out the influence trend of the variation of the discharge ratio on the real W2KDS efficiency at 60 rpm constant rotation and the results as shown in the curve in Figure 19.

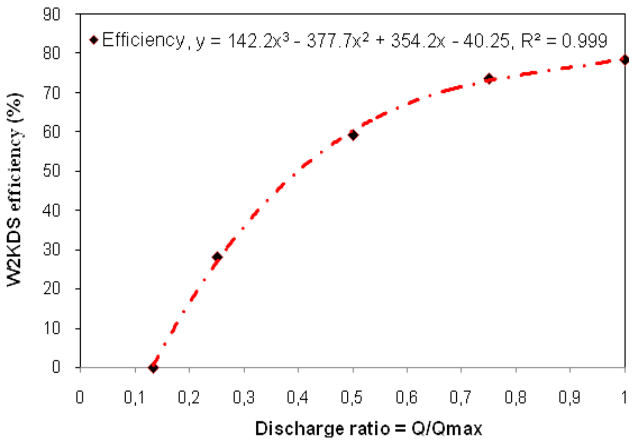


Fig. 19 Variation in the efficiency W2KDS versus discharge ratios

The efficiency curve trend is to produce a quadratic curve with a convincing coefficient of determination approaching value 1. This value confirms that the diversity of W2KDS efficiency values is proportional to the discharge ratio values' diversity. Furthermore, it can be analyzed that at the discharge ratio (Q/Q_{max}) below 0.143, the turbine efficiency reaches the lowest point, meaning that at that interval, W2KDS has not been able to produce power. Starting from the larger discharge ratio from 0.143 to 0.750, the increase in efficiency increases significantly; this indicates that W2KDS is quite sensitive in terms of increasing power changes due to the addition of water discharge. Furthermore, from the change in the discharge ratio of 0.750 to 1.000, it produces a trend of efficiency that gradually increases, as seen from the increase in the sloping curve. This situation explains that W2KDS starts to be saturated or less sensitive to changes in the discharge ratio above 0.750, this is due construction of blade runners who cannot match or adjust to the addition of water discharge. The highest efficiency of W2KDS is 78.4% at a discharge ratio of 1.00, which is the performance parameter of W2KDS.

E. W2KDS Efficiency Curve with Conventional Turbines as Comparison

The standard water turbine efficiency curve and reference for turbine practitioners and observers is the efficiency curve of five conventional turbines with a discharge ratio as a fixed variable. In this curve, it is known that W2KDS has a starting discharge that competes with crossflow turbines and Pelton turbines and is superior to Francis and Propeller turbines. This case can occur because Cross Flow Turbines, Pelton Turbines and W2KDS include action turbines while Francis Turbines and Propeller Turbines include reaction turbines. This phenomenon shows that the action turbine is more reactive than the reaction turbine. W2KDS has a trend of efficiency that regularly rises according to the addition of the value of the discharge ratio. While the efficiency trend of Cross-Flow Turbines and Pelton Turbines increased dramatically in the initial moments or the discharge ratio value is below 0.25, and the discharge ratio is above 0.25 to 1.0 the trend of relative efficiency remains relatively even tends to decrease. Furthermore, observing the curve of Figure 20, it is known that the W2KDS efficiency achievement is lower than that of all conventional turbines, especially with the Francis turbine. This result is because W2KDS is not equipped with directional blades or nozzles so that the direction of water entering the impeller is less focused and the water velocity becomes relatively slower.

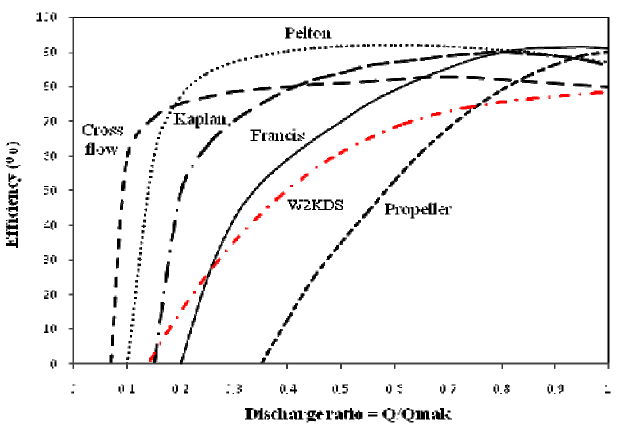


Fig. 20 Trend of efficiency versus discharge ratio of five conventional turbines compared to W2KDS

F. Efficiency of the transmission system W2KDS

Efficiency testing of a two-tier pulley belt transmission system (η_t) with a ratio of 16 is done by a braking mechanism to determine the torque that occurs on the W2KDS shaft and the torque that occurs on the rice milling shaft. The transmission system's efficiency can be determined by comparing the power of the rice milling (P_r) with real power W2KDS (P_w) as explained in Table 4. Figure 21 shows the trend of efficiency producing a linear curve which means that transmission efficiency is significantly and dominantly affected by real power variations of W2KDS. The greater the real power transmitted, the greater the loss of rotation due to slip, the greater the transmission system's loss of power. At a real power position of 310 W or at a discharge position of 25% a maximum transmission efficiency of 96.7% is produced, and at a real power position of 3460 W or a 100% discharge position, the minimum transmission efficiency is 88.2%.

TABLE IV
DATA TRANSMISSION SYSTEM EFFICIENCY TESTING

No	Q/Q_{max}	P_W (W)	P_r (W)	η_t (%)
1	0.25	310	300	96.7
2	0.50	1310	1210	92.5
3	0.75	2440	2230	91.4
4	1.00	3460	3050	88.2

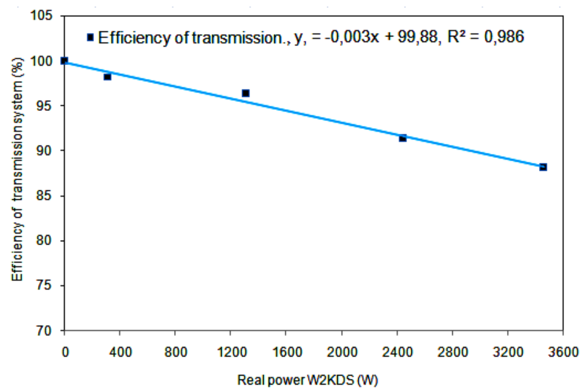


Fig. 21 Variation in the efficiency of transmission of real power

G. Productivity of Rice Milling

Table 5 describes the data from the rice milling productivity test results, and Figure 22 shows the trend of productivity variations due to the influence of variations in debit. There is a direct correlation between productivity and visible discharge from a rising linear curve. At a maximum discharge of 90.0 L/s, the amount of rice produced for five minutes (W_r) is 7.20 kg, the maximum productivity of rice milling (PRM) is 86.40 kg/h. The starting discharge when the W2KDS is functioned as a rice milling drive around 13 L/s, there is a decrease of 1 L/s compared to the start discharge when testing with braking that is 13 L/s.

TABLE V
DATA RICE MILLING PRODUCTIVITY TESTING

No	Q (L/s)	t (minutes)	W_r (kg)	PRM (kg/h)
1	22.5	5	1.08	12.96
2	45.0	5	2.87	34.44
3	67.5	5	5.23	62.76
4	90.0	5	7.20	86.40

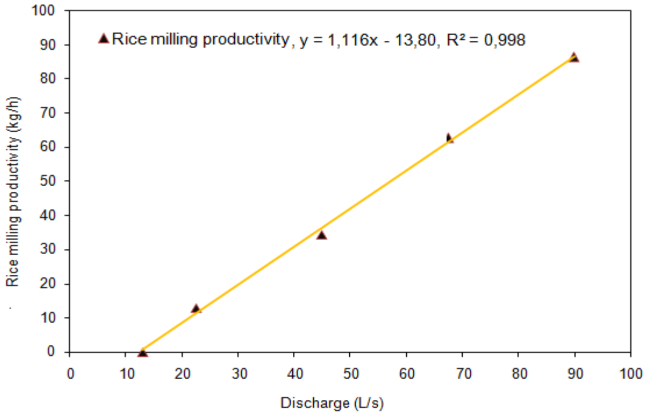


Fig. 22 Rice milling productivity versus discharge

IV. Conclusion

This experimental study succeeded in building the W2KDS system as a driver of rice milling. The type of water wheel is breastshoot, outer diameter 180 cm, inner diameter 120 cm, width 60 cm, type of blade adopts crossflow turbine blade design, number of blades 20 pieces. The test is carried out with four discharge variations, namely 25% discharge or 22.5 L/s, 50% or 45 L/s, 75% or 67.5 L/s, and 100% discharge or 90 L/s. At 100% discharge or 90 L/s, 5 m head and 60 rpm constant speed produced maximum performance, namely real power W2KDS 3460 W, the efficiency of W2KDS 78.48%, the efficiency of two-level pulley belt transmission system with a ratio of 16 is 88.2%, and the productivity of rice milling is 86.40 kg/h with a starting discharge of 13 L/s. The cost of producing rice milling is very cheap because it does not need fuel oil, so the W2KDS-rice milling system is suitable for development in isolated villages far from where fuel is sold. This study's results can inspire other researchers to produce a design and build two-function W2KDS, namely during the day as a driver of agricultural processing machinery and at night as an electric generator driver so that it can contribute more to the village community, especially to farmers.

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